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Robotic Technologies for the Future Force – The ART STO

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ABSTRACT

The Army has a need to integrate robotic technologies, leveraged from both Army and commercial sector developments, into an FCS Armed Robotic Vehicle (ARV) class chassis. The US Army's ARV Robotic Technologies (ART) Science and Technology Objective (STO) will develop a surrogate platform that will be used as a technology demonstrator for such robotic technologies. The ART STO will develop, integrate and demonstrate the technology required to advance the maneuver technologies (i.e., perception, mobility, tactical behaviors) and increase the survivability of unmanned platforms for the future force. The ART STO will focus on reducing the soldiers' burden by providing an increase in vehicle autonomy coinciding with a decrease in the total number user interventions required to control the unmanned assets.

INTRODUCTION

The main thrusts of the ART STO program are: advancing the Unmanned Ground Vehicle (UGV) perception, developing UGV tactical behaviors, and increasing the UGV survivability. This program will advance the state of the art in perception technologies to provide the unmanned platform an increasingly accurate view of the terrain that surrounds it; while developing tactical/mission behavior technologies to provide the UGV the capability to maneuver tactically, in conjunction with the manned systems in an autonomous mode. The program will also develop new capabilities to increase survivability of unmanned platforms by analyzing current UGV vulnerabilities and developing unique countermeasures. A UGV Modeling and Simulation (M&S) Suite will be developed and used as a tool for advanced mobility concepts/technologies (to include tactical behaviors and UGV survivability) using high-fidelity models of ARV platforms and subsystems with an equally accurate representation of the terrain. The surrogate platform will be integrated with the advanced technology software and associated hardware developed under this effort. It will also incorporate appropriate mission modules (e.g. RSTA sensors, MILES, countermine, etc.) to support Warfighter experiments and evaluations (virtual and field) in a military significant environment (open/rolling and complex/urban terrain).

THE ROBOTIC FUTURE FORCE

The use of robotics in the future force of the Army will change the face of the battlefield dramatically. Unmanned Ariel Vehicles (UAV's) have been used recently to some extent in our efforts in Afghanistan and Iraq, but their use will increase in the future; along with the addition of various sizes of UGV's ranging from the man-portable systems to larger systems that have the capabilities to engage the enemy. In the next few sections, the main UGV platforms and technology areas of the future force will be briefly described.

SMALL UNMANNED GROUND VEHICLE (SUGV)

The SUGV, a concept of which is shown in figure 1, will be a man-portable robot system, weighing less than 30 lbs. It will consist of a robotic Operator Control Unit (OCU), a robotic chassis platform with video capability, digital communications/audio relay modules (plug in/out), and advanced sensors/mission modules. These proposed systems will be autonomous and highly mobile for dismounted forces as well as, be capable of being re-configured for other missions by adding or removing sensors, modules, mission payloads, and/or subsystems.

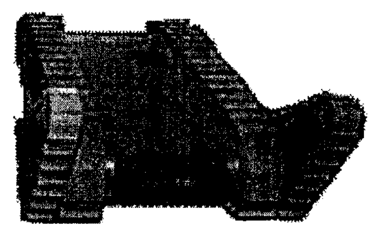

Figure 1 – SUGV concept

The SUGV will support the following tasks; remotely provide reconnaissance capability in MOUT and subterranean battlespace; remotely deploy sensors; employ dynamic payloads and special munitions into buildings, bunkers, tunnels, sewers, and other urban features; remotely detect and neutralize booby-traps, landmines, and explosive threats to forces in buildings, bunkers, tunnels, sewers, and other urban features; remotely locate or by-pass threat obstacles in buildings, bunkers, tunnels, sewers, and other urban features; remotely detect subterranean avenues of approach to prepare obstacle plans; remotely assess bomb damage and subterranean structural integrity of facilities and buildings; and act as a communications relay.

MULTIFUNCTIONAL UTILITY/LOGISTICS AND EQUIPMENT (MULE)

The Multifunctional Utility/Logistics and Equipment (MULE) Vehicle is a 2.5-ton UGV that will support

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dismounted operations by providing the capability to transport equipment and/or supplies in support of dismounted maneuvers. This is a multi-functional platform, capable of directly following the dismounted maneuver systems or being directed to move to positions not along the line of movement.

The MULE Vehicle has three variants, all conceptually shown in figure 2, sharing a common chassis: transport, countermine and the Armed Robotic Vehicle-Assault Light (ARV-AL). The transport MULE will carry 1,900-2,400 pounds of equipment and rucksacks for dismounted infantry squads with the mobility needed to follow squads in complex terrain. In addition to providing the capability to carry the soldiers supplies the transport MULE can be used as a medical evacuation platform if necessary. The countermine MULE will provide the capability to detect, mark and neutralize anti-tank mines by integrating a mine detection mission equipment package from the Ground Standoff Mine Detection System (GSTAMIDS) FCS program. The ARV-AL MULE is a mobility platform with an integrated weapons and reconnaissance, surveillance and target acquisition (RSTA) package designed to support the dismounted infantry's efforts to locate and destroy enemy platforms and positions.

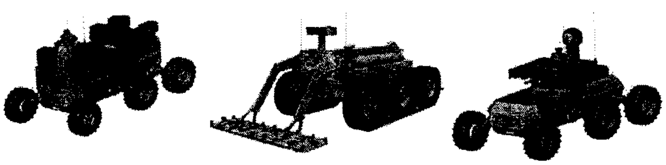

Figure 2 – Concept MULE Variants (from R to L, transport, countermine, and ARV-AL)

ARMED ROBOTIC VEHICLE (ARV)

The ARV will be used to rapidly shape the battlespace and provide force protection that enhances operational and tactical flexibility. These proposed systems will be unmanned and highly mobile to support mounted and dismounted forces. The ARV will be used to investigate features including structures, field fortifications, bunkers, and facilities. The ARV comes in two variants that share a common chassis: the Assault variant and the Reconnaissance, Surveillance and Target Acquisition (RSTA) variant. Both variants will provide remote reconnaissance capability in MOUT and other battlespace areas; be able to remotely deploy sensors; be equipped with a direct-fire weapon as well as other special munitions that can be fired into buildings, bunkers, and other urban features; remotely locate or by-pass threat obstacles in buildings, bunkers, and tunnels, and other urban features; have the ability to perform BDA; and acts as a communications relay.

The assault variant, a concept of which is depicted in figure 3, will also be integrated with video capability, digital communications/audio relay modules (plug in/out), and advanced sensors/mission modules; in addition to offensive weapons for both LOS and BLOS engagement capability. This will allow it to occupy key terrain and provide over-watching fires.

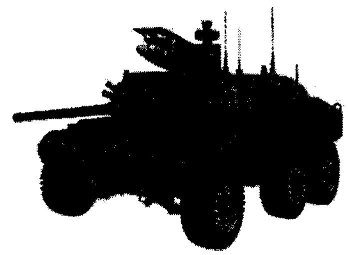

Figure 3 – ARV Assault concept

The RSTA variant, a concept of which is depicted in figure 4, will be integrated with payloads that provide video capability, digital communications/audio relay modules (plug in/out), and advanced sensors/mission modules, its payloads will generally be controlled by an operator in another vehicle, or by a dismounted operator.

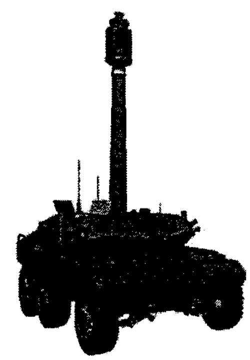

Figure 4 – ARV-RSTA concept

THE ART STO EFFORTS

TARDEC is currently going through the solicitation process for receiving proposals from perspective bidders on an ART STO integration contract. The intent is to award a single cost-plus-fixed-fee contract as a result of this solicitation and the request being issued on a full and open competition basis. Due to this fact, some of the main details of the ART platform are yet to be determined, since the prime contractor for the effort has not been selected to date. At the time of this writing it is estimated that the contract will be award around February 2005.

The main focus of the ART STO is to develop and mature robotic technologies in the areas of perception, tactical behaviors, and unmanned vehicle survivability. The above listed technologies will be integrated along with technologies leveraged from various Army and commercial sector developments, into a representative Future Combat Systems (FCS) ARV platform, to be used to support demonstrations of these technologies during operational field tests. This platform will be used as a technology demonstrator for the ART STO program as a step toward furthering the risk reduction efforts of the FCS ARV program, as well as transitioning additional

technologies to PM UA and the FCS Lead System Integrator (LSI).

Since this is a technology development effort and not program focused on the platform development or the specific platform mobility; the ART vehicle does not need to meet the entire mobility envelope of the ARV program. That being said, due to the fact that some of the technologies to be developed are platform specific we need to try and have the platform be at least a representative facsimile of the objective ARV platform. Table 1 lists the initial and final intrinsic mobility requirements that the ART platform will need to achieve.

Mobility Characteristic	Initial Requirement	Final Requirement
Hard Surface Roads	40kph (24.9mph)	50kph (31mph)
Cross Country	30kph (18.6mph)	40kph (21.7mph)
Acceleration	0 to 48 kph (29.8mph) in 15 sec	0 to 48 kph (29.8mph) in 10 sec
Grade	60% slope @ 5kph	60% slope @ 5kph
Slide Slope	laterally traverse, 40% slope	laterally traverse, 40% slope
Vertical Step	0.5m(1.64ft)	0.5m(1.64ft)
Gap	0.75m(2.46ft)	1m(3.28ft)

Table 1 – ART Platform Intrinsic Mobility Requirements

The other main focus areas of the STO will be broken out in detail in the following sections. These include UGV Perception, UGV Tactical Behaviors, UGV Survivability, ART STO Modeling and Simulation Efforts, Platform Mission Module Integration, and the ART STO Experiments.

UGV PERCEPTION

In order to navigate through the battlefield the UGV must have the ability to sense what its surroundings are. This perception of obstacles, personnel, and vehicles; combined with the intrinsic mobility of the mobility platform itself; will determine how and where the vehicle will travel. The intrinsic mobility and size of the robotic platform are directly related to the fidelity of perception that is required. The smaller a UGV, is the more terrain information it requires in order to determine its navigational path. For instance, an obstacle that might incapacitate a small robot might be too small to affect a larger robot; due to the fact that the larger vehicle can drive over the obstacle.

The ART STO effort is a joint effort between TARDEC and the Army Research Lab (ARL). One of the main items that ARL will be providing to the effort is an Autonomous Mobility System (AMS). The AMS will be provided to the ART integration contractor as Government Furnished Equipment (GFE). The contractor will be required to use the AMS as a starting point in its development of the Semi-Autonomous Perception Suite that is required for the effort. The perception suite contains the GFX Autonomous Mobility System; as well as including the ability to operate in inclement weather conditions, operate with opaque sensors, and the capability to sense-thru-the-blank (i.e. negative obstacle detection, foliage, etc). The contractor shall advance and mature the capability of the autonomous mobility suite by examining the current state-of-the-art perception technology to ensure the autonomous mobility suite meets the requirements.

In addition to increasing the amount of perception that will be provided for vehicle mobility, the perception system will be optimized to include technology for assuring high-reliability avoidance of humans and moving vehicles in close proximity to the ART platform. In particular, it will provide the ability for the platform's perception system to differentiate between moving and stationary obstacles, as well as track moving obstacles (vehicles and pedestrians). In the case of moving obstacles, the enhanced perception system shall generate a predictive trajectory which is used by the vehicle's path planner to safely avoid any contact with humans or vehicles. This shall be demonstrated at threshold speeds, for both on-road and cross country maneuvers. Safe operational measures that reflect the intended operational procedures of the fielded armed robotic vehicle will also be incorporated. Currently, most robotic systems use a chase vehicle or an on-board safety driver to ensure the safety of the UGV. In the future there needs to be a change in these standards since the actual fielded systems will need to be fully autonomous during the course of their missions.

UGV TACTICAL BEHAVIORS

The unmanned assets that are placed in the field must have the ability to maneuver around the battlefield undetected by the enemy with minimal user intervention. Enabling the UGV to complete its mission autonomously is critical to achieving the acceptance from the user. If constant interaction is required then there is little or no benefit to the soldier in the field.

The ART vehicle will utilize an embedded tactical behaviors suite to reduce the amount of user intervention that is required for the vehicle to perform its tasks. The tactical behaviors suite will provide the required levels of on-board intelligence to include, but not be limited to; cooperative maneuvers and engagements, manned/unmanned and unmanned/unmanned teaming, stealth, urban operations, and adaptive reasoning. This suite shall include a methodology/architecture for implementing the behaviors that is compatible with the FCS ARV hardware and software architecture. The behaviors will be integrated into the M&S suite for rapid development prior to their actual integration into the vehicle.

UGV SURVIVABILITY

Since the unmanned assets will be placed in the field to maneuver autonomously, there will be no armed

personnel to protect the system from being tampered with. The system will need both lethal and non-lethal methods to deter any enemy forces from disabling the system. These methods also require the ability to detect and track dismounted forces and distinguish combatants from non-combatants. Since the UGVs are required to be able to operate in all types of terrain (e.g. on-road, off-road, urban, etc.) this technology will be extremely important to the safety of our soldiers as well as the friendly people in the deployment area. The initial portion of this development is the process of conducting a vulnerability/threat assessment for unmanned ground platforms. From this assessment, an UGV survivability suite will be developed. It will include an integrated, aided, non-lethal, anti-tamper suite. This suite will provide increasingly higher levels of deterrence and countermeasures, spanning the spectrum from verbal warning to immobilization.

Embedding vehicle prognostics and diagnostics is a focal point for the future force, but once you remove the man from the vehicle asset the problem becomes significantly more difficult to solve. When a person is in a vehicle they have multiple sensory inputs including those that are visual and audible, that will need to be identified by the UGV as well. An example of this is the knocking of an engine, I person can detect this by either hearing or feeling the knock, and then determine how to handle the situation with the engine. The computer that is controlling the UGV however does not posses this sensory capability; it is this situation that the ART STO will focus on. An embedded prognostic and diagnostics suite will be developed that addresses specifically the unmanned platforms unique prognostic and diagnostics situations such as the one that was described above.

ART STO MODELING AND SIMULATION (M&S) EFFORTS

The M&S suite will be developed to test, evaluate, and refine the ART final and surrogate vehicle subsystem concepts and technologies in a constructive, and virtual simulated environment. The M&S suite will also be used to refine the tactical behaviors and survivability functionality during the life cycle of the program. Once the M&S suite is developed it will be provided to the Unit of Action Maneuver Battle Lab (UAMBL) at Fort Knox to be used in the development of Techniques, Tactics and Procedures (TTP's) for UGV's. The M&S suite will also be used to support laboratory testing of the Human Robot Interface (HRI) Operator Control Unit (OCU). The suite will operate with sufficient functionality to demonstrate key technology and user interface features of the ART concepts.

In addition to the capabilities described above, the M&S suite will be integrated with the One Semi-Automated Forces (OneSAF) Testbed (OTB) and capable of interacting with OTB entities. The M&S Suite will also be capable of ingesting an OTB Compact Terrain DataBase (CTDB) interacting with terrain features, and generating synthetic sensor imagery. The interface, with other simulated entities will be through a standard COTS link that supports the High Level Architecture guidelines of the current standard interface protocol supported by the Army for distributed simulations.

The final portion of the ART M&S suite is an object model of the vehicle using Universal Modeling Language (UML) or Web Ontology Language (OWL) to support the Government's analysis of the ART conceptual design. The object model will define the components of the ART vehicle, the external objects with which the ART interacts, and the ART's tactical behaviors. An ART Vehicle model comprised of the primary ART subsystem and Vetronics component models will be developed to support integration with the TARDEC Virtual SIL. The models shall be implemented utilizing HLA, Matlab, and J2EE. The models will be constructed to simulate the production and consumption of Vetronics attributes supporting systems engineering analysis of the ART system to include power, data throughput, data latency, processor throughput, memory utilization, thermal loading, and package volume.

PLATFORM MISSION MODULE INTEGRATION

The amount of new technology that is needed to achieve the entire required capabilities for the unmanned assets of the future force is astronomical. The integration of these multiple technologies onto a single platform such that they can all seamlessly interact will be an enormous challenge. Each individual system will require specific data in order to determine its current situational awareness. This data will more than likely come from a n external sensor. Because all components of weapon systems are subject to space limitations, some amount of sensor sharing/fusion must take place. Since TARDEC is mainly focused on ground vehicles and the associated technology that enables those technology aspects, we are planning on leveraging other technologies from the rest of the Army's R&D community. In the following sections, the main mission modules that we are looking at leveraging will be discussed, all of these mission modules will be integrated and matured to meet the needs of the ART STO program.

For the past 10 years, TARDEC has been conducting multiple efforts regarding the interface between the user and the robotic assets, the main program that is currently running is the Crew integration and Automation Testbed advanced Technology Demonstrator (CAT ATD). These interfaces range from a three display system that can be mounted in a combat vehicle down to an interface that can be run on a hand held PDA. The goal of the efforts is to develop a common scalable user interface that maximizes multi-functional soldier performance of primary mission tasks by minimizing required interactions and workload in the control of ground and air unmanned systems while minimizing unique training requirements, through the development and application of advanced tools and technologies to reduce the overall requirement and time need for the soldier to control the unmanned

systems and accelerate fielding of soldier-robot teams. The CAT ATD program is advancing the application of autonomous mobility developments to help aid in driving both manned and unmanned vehicles in a variety of element configurations. The program's long-term goals are to develop advanced technologies that will reduce crew sizes while increasing operational effectiveness. Thus, the crewstation shown in figure 5, was developed to support a command & control environment that is well suited for combat operations. The integrated crewstation was developed using interface standards for the variety of displays presented to the soldier. These standards address such factors as: consistency among displays, increased operator situation awareness of the current state of the displays, operation in a moving vehicle using protective gear, and presentation of the material in a useful and appropriate manner. The primary tools used to accomplish these objectives include careful interface design, integrated intelligent aiding of soldier tasks and a robust speech-recognition interface.

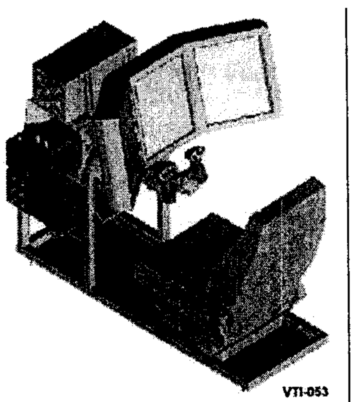

FIGURE 5

Since one of the main variants of the ARV is the RSTA variant some facsimile of a future RSTA system needs to be integrated onto the ART platform. We are working in conjunction with the Army's Night Vision Labs (NVL) to integrate their Target Acquisition Sensor Suite (TASS) that will provide the capability to see/sense environment, provide shaped based Aided Target Detection and Recognition in a ground environment and demonstrate a low cost long range ID capability.

One of the main catalysts for the future force is providing a networked fire control capability. TARDEC has been working with AMRDEC on their Fire Control-Node Engagement Technology (FC–NET) STO program for the past 3 years. The main initiative of the FC-NET STO is to develop a common Technical Fire Control Architecture (TFCA) for the Future Combat Systems (FCS) family of vehicles. The TFCA is a modular software architecture that provides a plug-and-fight capability for the UA. Technical fire control systems are normally embedded in a weapon system and focus on the computational and mechanical operations required for that weapon system to hit a specific target with specific munitions. The other main component of the FC-NET STO is a set of Weapon Target Pairing Algorithms (WTPA). These are decision aided assignment of fire units and munitions (guns or missiles) to a designated target, based on calculated criteria to maximize the effectiveness of the tactical assault.

The actual lethality system that will be integrated on the ART platform is still under examination. We have been working with both ARDEC and AMRDEC on potential surrogate packages, but nothing is definite at this time. At a minimum, the ART platform will have a simulated lethality package integrated on the system with the goal being a fully functional system that can be used in conjunction with a live-fire testing in FY08. We are looking at the integration of both a short range weapon, such as the Advanced Crew Served Weapon (ACSW) or M240 machine gun, as well as longer range weapon such as a Javelin Missile or MK44.

The communications network that will be used in the future force is a critical area that needs to be developed and integrated as soon as possible. CERDEC has many efforts working on increasing the amount of communications bandwidth available for the future force. We are examining some of the potential programs that we can leverage, but most are either unrealistic or will not be available in time for our integration efforts. During the testing time frame, we will integrate either the latest military radios that are being developed under the Joint Tactical Radio System (JTRS) program or the Soldier Level Integrated Communications Environment (SLICE) program.

ART STO EXPERIMENTS

There are currently two main experimentations that are planed as part of the ART STO efforts: an initial baseline experiment in September of 2006 and a final experiment in March of 2008. Each experiment will consist of two experimental components: a set of engineering evaluation tests (EET's) and operational experiment. The EET's will demonstrate and validate the capabilities of the systems to meet the performance requirements; while the operational experiments will examine the operational capabilities of the systems and provide a mechanism for user feedback. During the operational experiment, actual soldiers will be operating the vehicle in a military relevant scenario on various terrains. Since most of the data that will be collected during the EET's is requirements based, it is not necessary that the vehicles be operated by actual users.

The main asset that will be used during the ART experiments is a surrogate ARV system integrated with the technology components described previously. The ART integration contractor (TBD) will acquire/develop a suitable vehicle which allows for the integrated vehicle to meet all of the vehicle requirements. The ART vehicle can be based off of an existing platform that is in the FCS ARV class, or developed from a concept. However, it is not the intent of the ART STO to develop a unique platform for this program.

The initial ART experiment in 2006 will be used to baseline the initial capabilities of the technologies developed for the ART STO. In addition, it will allow for verification and testing of the mission modules that will be integrated onto the ART platform. This experiment will be held in conjunction with other S&T efforts in order to reduce the costs associated with field testing. The final experiment in 2008 will serve as the culmination of the ART STO effort; it is at this time that all of the exit criteria must be meet and that the technologies developed must be ready for transition to the PM UA and the LSI.

CONCLUSION

Currently the fielded force of today's Army has little or no unmanned assets on the battlefield, over the next 10 years the number of UV's, whether they are air, ground, or water vehicles, which will be fielded will grow dramatically. TARDEC's ART STO is developing some of the main component technologies that will be needed to achieve the user acceptance required for this fielding to begin. In the process of this technology development the ART STO will develop a surrogate ARV platform that can be used as an integration testbed for other S&T programs. There is a need for additional technological components outside of the TARDEC scope in order to encompass the overall ARV concepts to provide the Army with the most mature S&T technologies for the future force. This effort is an excellent opportunity to leverage assets and testing across the Army and commercial sectors since we all have a common goal to serve our customer -- the warfighter!!

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CONTACT

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ACRONYMS

ACSW	Advanced Crew Served Weapon
AMRDEC	Aviation and Missile Research, Development, and Engineering Center
AMS	Autonomous Mobility System
ARDEC	Armament Research, Development, and Engineering Center
ARL	Army Research Labs
ART	ARV Robotic Technologies
ARV	Armed Robotic Vehicle
ARV-AL	Armed Robotic Vehicle – Assault Light
BDA	Battle Damage Assessment
BLOS	Beyond Line Of Sight
CAT	Crew integration and Automation Test bed
CERDEC	Communications and Electronics Research, Development, and Engineering Center
COTS	Commercial Off The Shelf
CTDB	Compact Terrain DataBase
EET	Engineering Evaluation Tests
FC-NET	Fire Control-Node Engagement Technology
FCS	Future Combat Systems
GFE	Government Furnished Equipment
GFX	Government Furnished Equipment/Software
GSTAMIDS	Ground Standoff Mine Detection System
HLA	High Level Architecture
HRI	Human Robot Interface
JTRS	Joint Tactical Radio System
LOS	Line Of Sight
LSI	Lead System Integrator
MOUT	Military Operations in Urban Terrain
NVL	Night Vision Labs
OCU	Operator Control Unit
OneSAF	One Semi-Automated Forces
ORD	Operational Requirements Document
OTB	OneSAF TestBed
OWL	Web Ontology Language
PDA	Personal Digital Assistant
RDECOM	Research, Development and Engineering Command
RSTA	Reconnaissance Surveillance & Target Acquisition
SAE	Society of Automotive Engineers
SIL	Simulation Integration Lab
SLICE	Soldier Level Integrated Communications Environment

STO	Science and Technology Objective
SUGV	Small Unmanned Ground Vehicle
TARDEC	Tank Automotive Research, Development, and Engineering Center
TASS	Target Acquisition Sensor Suite
TFCA	Technical Fire Control Architecture
TTP	Techniques, Tactics and Procedures
UA	Unit of Action
UAMBL	Unit of Action Maneuver Battle Lab
UAV	Unmanned Air Vehicle
UGV	Unmanned Ground Vehicle
UML	Universal Modeling Language
WTPA	Weapon Target Pairing Algorithms